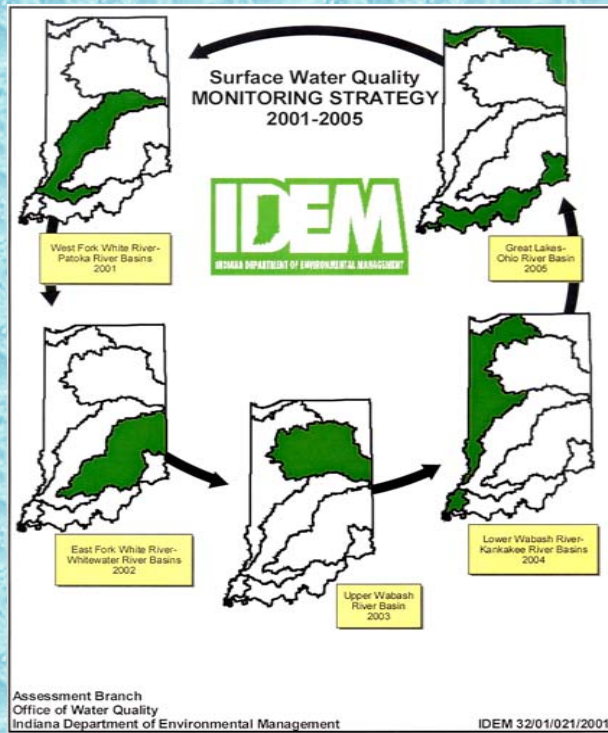# Implementation of Indiana's Probabilistic Watershed Monitoring Program and Second Year Source Identification Sampling

Presented by:

Stacey L. Sobat

Biological Studies Section

IDEM/Office of Water Quality/Assessment Branch

Overview of Presentation

- **Monitoring Design: why it was selected, how it is used, and products produced**

- **Second year source identification sampling**

- **Strengths and weaknesses of using probabilistic monitoring**

Goal of Indiana's Water Quality Standards

- State's Goal: "… to restore and maintain the chemical, physical, and biological integrity of the waters of the State." 327 IAC 2-1-1.5

- Historically, targeted sites related to point source pollution

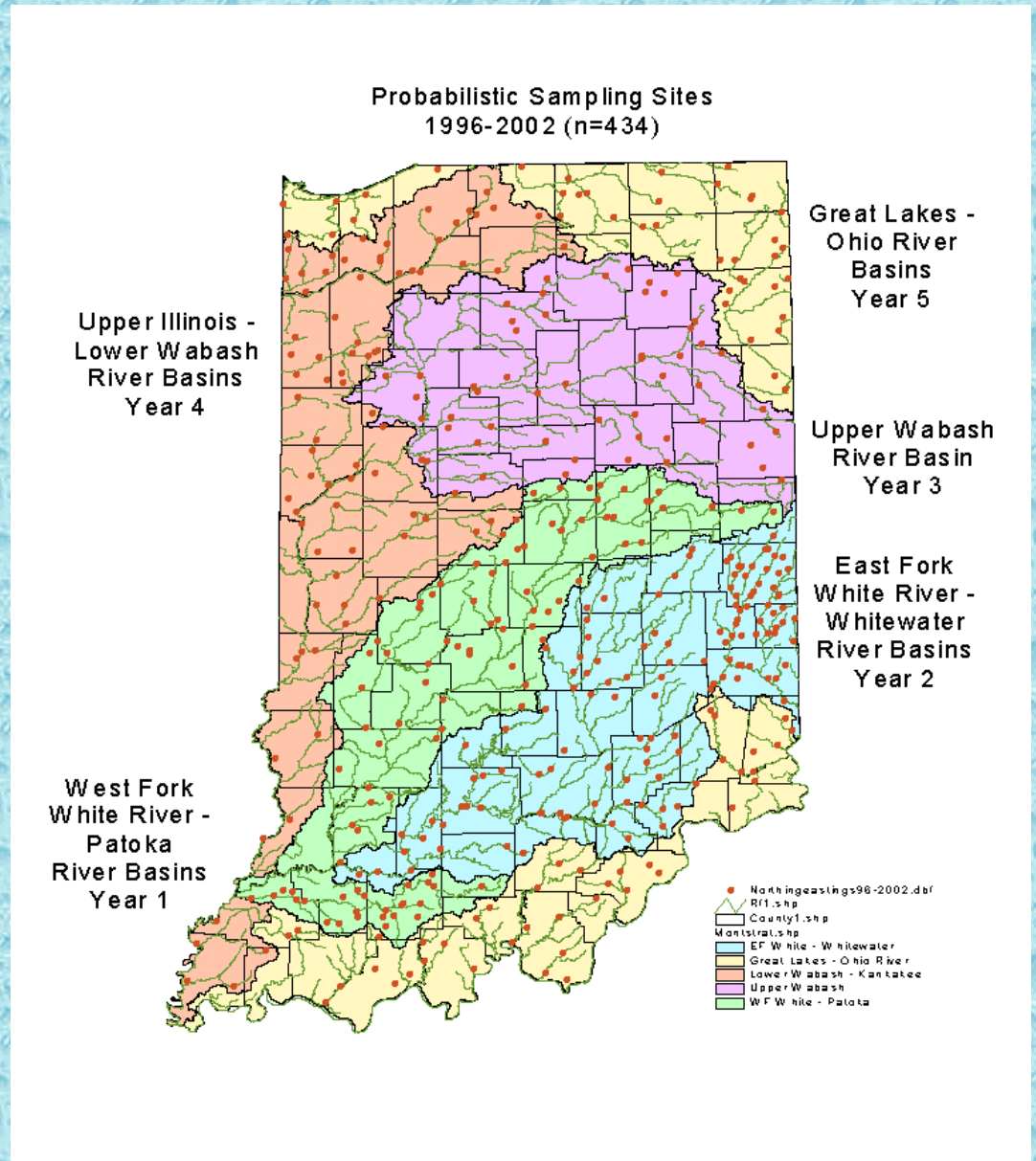- Shift to non-point source pollution & ALL waters of the state

Probabilistic Monitoring Design

•**Rivers and streams are sampled by targeting watershed basins and sampling them every 5 years**

–**Year 1: WFWR & Patoka**

–**Year 2: EFWR & Whitewater**

–**Year 3: Upper Wabash**

–**Year 4: Lower Wabash & Kankakee**

–**Year 5: Great Lake & Ohio R. tribs**

Probabilistic Sampling Sites
1996-2002 (n=434)

Great Lakes -
Ohio River
Basins
Year 5

Upper Illinois -
Lower Wabash
River Basins
Year 4

Upper Wabash
River Basin
Year 3

East Fork
White River -
Whitewater
River Basins
Year 2

West Fork
White River -
Patoka
River Basins
Year 1

Northingeastings96-2002.dbf
Rf1.shp
County1.shp
Montstrat.shp
EF White - Whitewater
Great Lakes - Ohio River
Lower Wabash - Kankakee
Upper Wabash
WF White - Patoka

Probabilistic Monitoring Design

•**USEPA Western Ecology Division generated probabilistic site locations**

•**Site Reconnaissance (Feb.-April)**

–**Topographic Maps**

–**Brochures**

–**Contact Landowner**

–**Site Accessibility & Equipment**
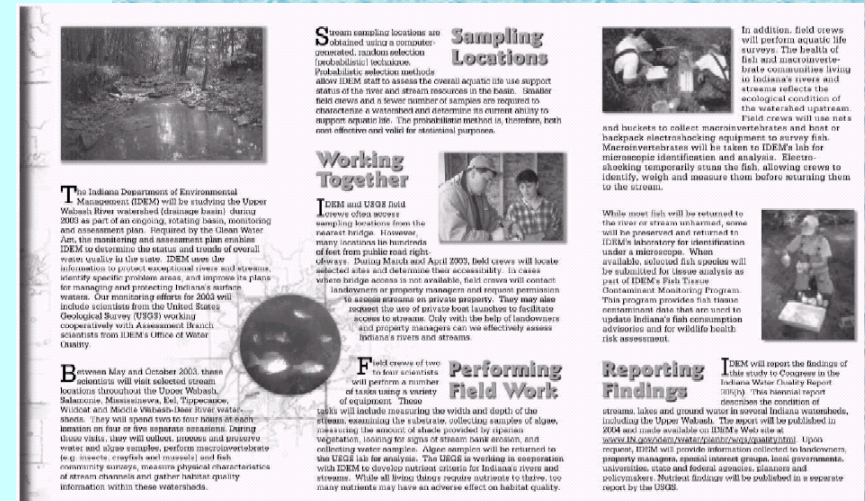
–**Enter Recon data**

•**Data Collected:**

–**Water, Nutrient, and Bacteriological Samples For Laboratory Analysis**

–**Macroinvertebrate Community Assessments**

–**Fish Community Assessments**

–**Habitat Assessments**

Water Chemistry, Nutrients, & *E.coli*

- Grab water samples and nutrients collected spring, summer, and fall (USGS contract)

- Chemistry Parameters

Priority Metals	Physical/Anions	Nutrients/Organic
Arsenic	Alkalinity	TKN
Calcium	Total Solids	Ammonia-N
Cadmium	Suspended Solids	Nitrate+Nitrite-N
Chromium	Dissolved Solids	Total Phosphorus
Copper	Sulfate	TOC
Lead	Chloride	Cyanide-Total
Magnesium	Hardness	Cyanide-Free
Mercury		COD
Nickel		
Selenium		
Zinc		

Water Chemistry, Nutrients, & *E.coli*

- **Hydrolab data collected during each sampling event:**

  –D.O., pH, Conductivity, Water temperature, Turbidity

- **Nutrients:**

  –Chlorophyll A in phytoplankton and periphyton samples, ash-free dry mass in periphyton samples

- **E.coli:**

  –each site sampled once each week for 5 consecutive weeks

Macroinvertebrate Community Assessments

- **KICK sample**

- **Hester-Dendy**

- **Laboratory Processing**

- **mIBI: 10 metrics (range = 0-8)**
  - 1. Family level HBI
  - 2. Number of taxa
  - 3. Number of individuals
  - 4. Percent dominant taxa
  - 5. EPT Index
  - 6. EPT Count
  - 7. EPT count to total number of individuals
  - 8. EPT Count to Chironomid Count
  - 9. Chironomid Count
  - 10. Total number of individuals to number of squares sorted

Fish Community Assessments

- **15 x the wetted stream width**
  (backpack, totebarge, boat electrofishing)

- **All stream sizes included**

- **Species Level Identification**

- **IBI: 12 metrics (range 6-60)**
  - 1. # species
  - 2. # darter species/ #dms species
  - 3. % headwater ind./ # sunfish sp.
  - 4. # minnow sp./ # sucker sp.
  - 5. # sensitive sp.
  - 6. % tolerant ind.
  - 7. % omnivore ind.
  - 8. % insectivore ind.
  - 9. % pioneer ind./% carnivore ind.
  - 10. Total # ind.
  - 11. % simple lithophils
  - 12. % DELT anomalies

Qualitative Habitat Evaluations (QHEI)

1. **Substrate**

2. **Instream Cover**

3. **Channel Morphology**

4. **Riparian Zone & Bank Erosion**

5. **Pool/Glide Quality Riffle/Run Quality**

• **Gradient**

Range 0-100

Stream Assessments Using Probabilistic Results

1. Any violations chemical or biological

–For chemical impairment:
Water Quality Standards [327 IAC 2-1-6]

–For biological impairment:

"all waters, except those designated as limited use, will be capable of supporting a well-balanced, warm water aquatic community."

[327 IAC 2-1-3(2)]

"well-balanced aquatic community" is "an aquatic community which is diverse in species composition, contains several different trophic levels, and is not composed mainly of strictly pollution tolerant species"

[327 IAC 2-1-9(49)].

Chironomid Photo by Dale Parker, AquaTax Consulting

Central stoneroller, *Campostoma anomalum*

Stream Assessments Using Probabilistic Results

Total IBI Score	Integrity Class	Attributes
58-60	Excellent	Comparable to best condition present in ecoregion conditions, exceptional assemblage of species.
48-52	Good	Decreased species richness (intolerant species in particular), sensitive species present. Deviation Minor.
40-44	Fair	Intolerant and sensitive species absent, skewed trophic structure. Deviation Slight.
28-34	Poor	Top carnivores and many expected species absent or rare, omnivores and tolerant species dominant. Deviation Moderate.
12-22	Very Poor	Few species and individuals present, tolerant species dominant, diseased fish frequent. Deviation severe.
<12	No Fish	No fish captured during sampling. Deviation very severe.

Stream Assessments Using Probabilistic Results
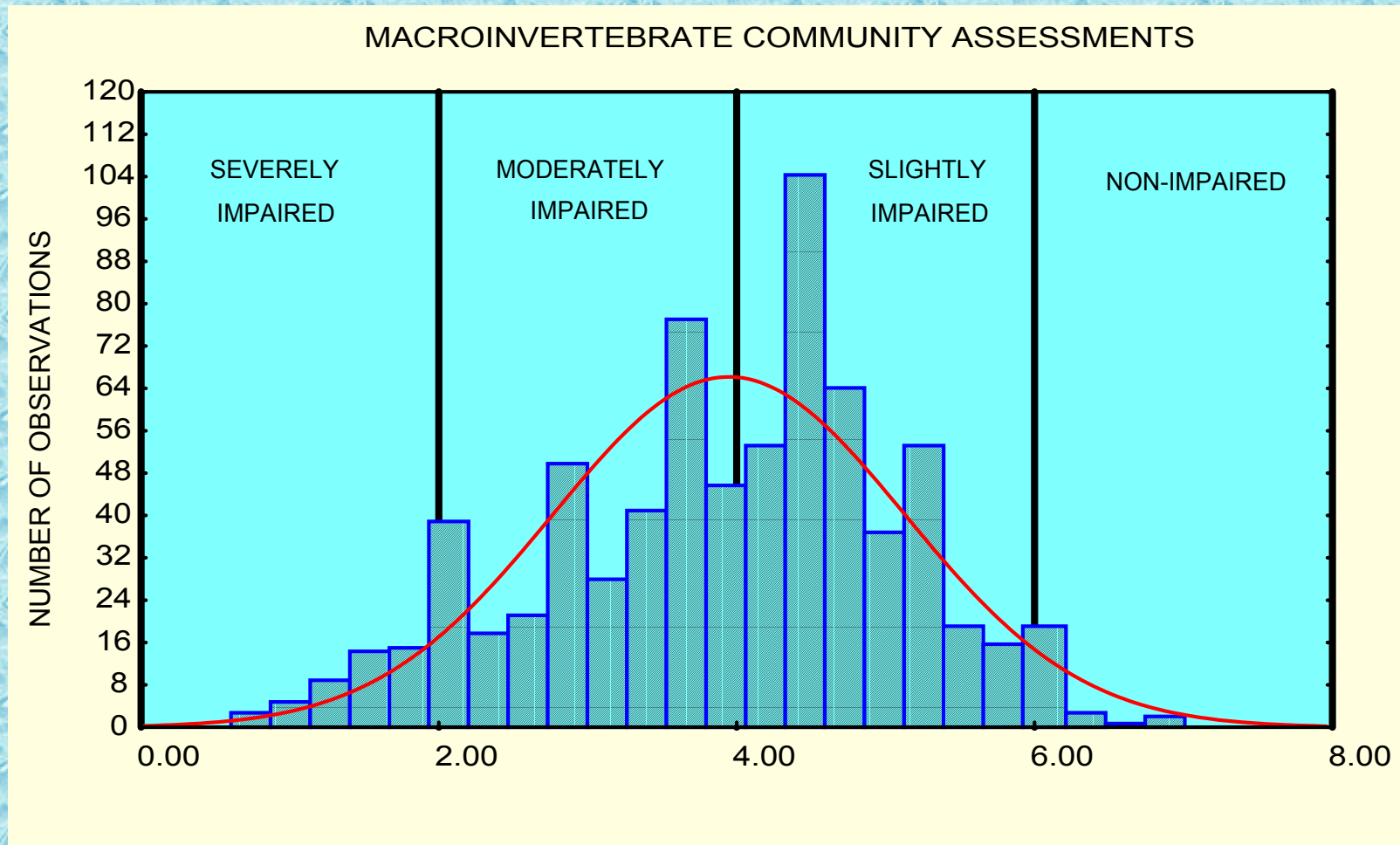
Photos by Dale Parker, AquaTax Consulting

Stream Assessments Using Probabilistic Results

1. Any violations chemical or biological:

–Fish Community: Impaired IBI $\leq$ 35

–Macroinvertebrate:

Impaired KICK mIBI < 2.2

Impaired Hester-Dendy < 1.4

2. Look for possible cause/source:

–habitat, type of chemical violation, likely source

3. How far to apply impairment:

–tributary influence, land use characterization, confined feeding operations, permitted facilities

Stream Assessments Using Probabilistic Results

1. Any violations chemical or biological

2. Look for possible cause/source

3. How far to apply impairment

4. Refer impaired sites for Source ID

5. Assess sites for Indiana's Integrated Water Monitoring and Assessment Report

6. Predict % Miles Attaining Aquatic Life Use Technical Reports Data Requests

INDIANA
INTEGRATED WATER MONITORING
AND ASSESSMENT REPORT
2002

Section 305(b) Water Quality Report
and
Consolidated List
Including Section 303(d) List of Impaired Waters
(Category 5)

Indiana Department of Environmental Management
Office of Water Quality
Planning and Restoration Branch
Indianapolis, Indiana

IDEM

IDEM/34/02/004/2002

Using Probabilistic Results to Predict the Percentage of Stream Miles Not Attaining Aquatic Life Use

1. **"R" software:** free software developed by the R Development Core Team along with many other contributors to allow the exchange of statistical packages and programming knowledge to anyone with an internet browser (http://cran.us.r-project.org/).

2. **Table compatible with "R" software**

3. **Example of "R" screen & language**

4. **Adjust weight function**

5. **Output from "R"**

–Basic Statistics (mean, variance, std.deviation)

–Cumulative distribution of stream miles for a numeric value (i.e. IBI score)

–Percent of stream miles attaining with confidence levels

6. **Assessment for River Basin**

```
SiteID   SiteName        County   RF3RCHID        MAP24K   MAP100K MAP250K Long.dd Lat.dd   Stratum MDCaty   Weight   StrahlerOrder
OECO.96  SiteIDF  Basin    HUC14Code        StrahlerOrder1   StatusB Fish.Community   Fish.IBI        Macroinvertebrate
Macro.IBI        Habitat QHEI    Overall.Biology Combined.Assessment      T.E
INRB01-201       PATOKA R        GIBSON  5120209    3  2.70     Union   PRINCETON       VINCENNES       87.38542
38.37718         6       12      31.471429       5       Interior River Lowland   INRB01-201      Patoka  5.12E+12        5
TS       I       18      NS      NA      I       36      I       I       A
INRB01-202       PATOKA R        DUBOIS  5120209   10 22.53     Cuzco   JASPER  VINCENNES       86.72151        38.44116
6        12      31.471429       3       Interior Plateau        INRB01-202      Patoka  5.12E+12        3       TS      NI
42       NS      NA      NI      62      NI      NI      A
INRB01-203               PIKE    5120209  356  0.00     Otwell  PRINCETON       VINCENNES       87.10332        38.44934
6        11      44.06   1       Interior River Lowland   INRB01-203      Patoka  5.12E+12        1       NT      NS      NA
NS       NA      NS      NA      NS      NS      A
INRB01-204       Youngs Creek    ORANGE  5120209   43  0.00     Greenbrier      JASPER  VINCENNES       86.52804
38.44448         6       13      22.03   2       Interior Plateau        INRB01-204      Patoka  5.12E+12        2       NT
NS       NA      NS      NA      NS      NA      NS      NS      A
INRB01-205               GIBSON  5120209  388  3.65     Union   PRINCETON       VINCENNES       87.45415        38.41468
6        13      22.03   2       Interior River Lowland   INRB01-205      Patoka  5.12E+12        2       TS      I       22
NS       NA      I       44      I       I       A
INRB01-206       PATOKA R        DUBOIS  5120209   10  8.00     Dubois  JASPER  VINCENNES       86.85355        38.44801
6        12      31.471429       4       Interior Plateau        INRB01-206      Patoka  5.12E+12        4       TS      I
22       NS      NA      NI      54      I       I       A
INRB01-207       Cup Creek       PIKE    5120209   18  0.00     Velpen  PRINCETON       VINCENNES       87.12247
38.32717         6       13      22.03   2       Interior River Lowland   INRB01-207      Patoka  5.12E+12        2       TS
I        30      NI      4       I       44      I       I       A
INRB01-208       HALL CR DUBOIS  5120209    9  3.18     Huntingburg     JASPER  VINCENNES       86.88277        38.35649
6        13      22.03   2       Interior Plateau        INRB01-208      Patoka  5.12E+12        2       TS      NI      38
NI       5.2     I       42      NI      NI      A
INRB01-209       Honey Creek     PIKE    5120209   30  0.00     Oakland City    PRINCETON       VINCENNES       87.27051
38.27522         6       11      44.06   1       Interior River Lowland   INRB01-209      Patoka  5.12E+12        1       TS
NI       46      NS      NA      NI      57      NI      I       A
INRB01-210       HALL CR DUBOIS  5120209    9  8.72     Saint Anthony   JASPER  VINCENNES       86.78765        38.36598
6        13      22.03   2       Interior Plateau        INRB01-210      Patoka  5.12E+12        2       TS      NI      40
NI       5.2     I       47      NI      NI      A
INRB01-211       PATOKA R        DUBOIS  5120209    6  2.24     Velpen  PRINCETON       VINCENNES       87.00374
38.36077         6       12      31.471429       5       Interior River Lowland   INRB01-211      Patoka  5.12E+12        5
LD       NS      NA      NS      NA      NS      NA      NS      NS      A
INRB01-212               DUBOIS  5120209  296  0.00     Huntingburg     JASPER  VINCENNES       86.98246        38.30035
6        11      44.06   1       Interior River Lowland   INRB01-212      Patoka  5.12E+12        1       TS      I       16
NS       NA      I       33      I       I       A
INRB01-213               PIKE    5120209  283  0.00     Petersburg      PRINCETON       VINCENNES       87.25887
38.38355         6       12      31.471429       4       Interior River Lowland   INRB01-213      Patoka  5.12E+12        4
NT       NS      NA      NS      NA      NS      NA      NS      NS      A
INRB01-214       PATOKA R        ORANGE  5120209   12 21.66     Valeene JASPER  VINCENNES       86.47832        38.44104
6        12      31.471429       3       Interior Plateau        INRB01-214      Patoka  5.12E+12        3       TS      NI
46       NI      3       NI      55      NI      NI      A
INRB01-215       FLAT CR PIKE    5120209   13  3.45     Otwell  PRINCETON       VINCENNES       87.0772 38.40348        6
```

Using Probabilistic Results to Predict the Percentage of Stream Miles Not Attaining Aquatic Life Use

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3. Example of "R" screen & language

4. Adjust weight function

5. Output from "R"

   – Basic Statistics (mean, variance, std.deviation)

   – Cumulative distribution of stream miles for a numeric value (i.e. IBI score)

   – Percent of stream miles attaining with confidence levels

6. Assessment for River Basin

```
R RGui - [R Console]

R  File  Edit  Misc  Packages  Windows  Help

Version 1.6.2   (2003-01-10)


R is free software and comes with ABSOLUTELY NO WARRANTY.
You are welcome to redistribute it under certain conditions.
Type `license()' or `licence()' for distribution details.


R is a collaborative project with many contributors.
Type `contributors()' for more information.


Type `demo()' for some demos, `help()' for on-line help, or
`help.start()' for a HTML browser interface to help.
Type `q()' to quit R.


[Previously saved workspace restored]


> {pkg <- select.list(sort(.packages(all.available = TRUE)))
+  if(nchar(pkg)) library(pkg, character.only=TRUE)}
> # File:  RPatokaBio.txt
> # Purpose:  2001 Patoka River Basin population estimates and weight adjustments
> # Programmer:  Stacey Sobat (Tony Olsen)
> # Date: March 19, 2003
> # Read in combined design file and site evaluation file at designstatus
> designstatusbio <- read.delim('designstatusbio.txt')
> names(designstatusbio)
  [1] "SiteID"             "SiteName"           "County"
  [4] "RF3RCHID"           "MAP24K"             "MAP100K"
  [7] "MAP250K"            "Long.dd"            "Lat.dd"
 [10] "Stratum"            "MDCaty"             "Weight"
 [13] "StrahlerOrder"      "OECO.96"            "SiteIDF"
 [16] "Basin"              "HUC14Code"          "StrahlerOrder1"
 [19] "StatusB"            "Fish.Community"     "Fish.IBI"
 [22] "Macroinvertebrate"  "Macro.IBI"          "Habitat"
 [25] "QHEI"               "Overall.Biology"    "Combined.Assessment"
> # Add equal area x,y coordinates to be used in variance estimation
> # Note that longitude must be changed to be negative
> tmp <- marinus(designstatusbio$Lat.dd,-designstatusbio$Long.dd)
Error: couldn't find function "marinus"
>
```

R 1.6.2 - A Language and Environment

Start | Microsoft PowerPoint - [O... | Exploring - Biology | RGui - [R Console] | RPatokaBio.txt - Notepad | 1:50 PM

Using Probabilistic Results to Predict the Percentage of Stream Miles Not Attaining Aquatic Life Use

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6. Assessment for River Basin

```
adjwgt.fcn          package:psurvey.analysis        R Documentation

Adjust Initial Survey Design Weights

Description:

     This function adjusts initial survey design weights when
     implementation results in use of oversample sites or when it is
     desired to have final weights sum to a known frame size.  Adjusted
     weights are equal to initial weight times the frame size divided
     by the sum of the initial weights.  The adjustment is done
     separately for each category specified in argument `wtcat'.

Usage:

     adjwgt.fcn(sites, wgt, wtcat, framesize)

Arguments:

   sites: the indicator value for each site (`T'=include the site and
          `F'=do not include the site)

     wgt: the initial weight for each site

   wtcat: the weight adjustment category name for each site

framesize: known size of the frame for each category name in  `wtcat',
          which must have the names attribute set to match the names
          used  in `wtcat'

Value:

     A vector of adjusted weights, where the adjusted weight is set to
     zero for  sites that have the indicator value in the `sites'
     argument set to  `F'

Author(s):
```

Using Probabilistic Results to Predict the Percentage of Stream Miles Not Attaining Aquatic Life Use

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   –Cumulative distribution of stream miles for a numeric value (i.e. IBI score)

   –Percent of stream miles attaining with confidence levels

6. **Assessment for River Basin**

File　Edit　View　Insert　Format　Tools　Data　Window　Help

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A14

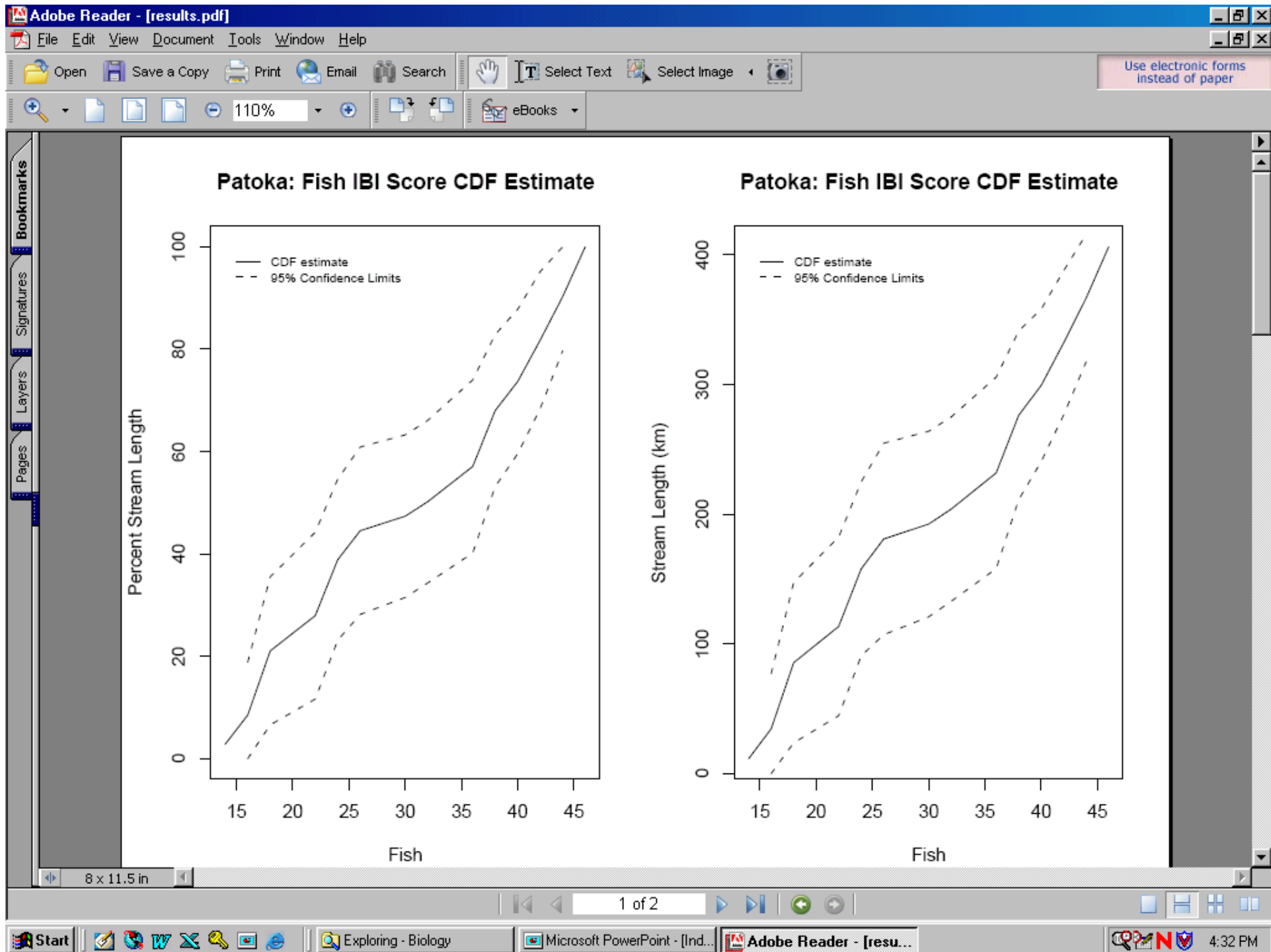|	A	B	C	D	E	F	G	H	I	J
1		Type	Subpopulation	Indicator	Statistic	NSites	Estimate.U	StdError.U	LCB95Pct.U	UCB95Pct.U
2	1	Basin	Patoka	Fish	Total	26	12776.659	902.321706	11008.141	14545.1771
3	2	Basin	Patoka	Fish	Mean	26	31.441296	1.7896686	27.93361	34.948982
4	3	Basin	Patoka	Fish	Variance	26	112.336762	13.2766416	86.315022	138.358501
5	4	Basin	Patoka	Fish	Std. Deviation	26	10.598904	0.6263214	9.371336	11.826471
6	5	Basin	Patoka	Macro	Total	12	624.848713	89.5294912	449.374135	800.323291
7	6	Basin	Patoka	Macro	Mean	12	3.452727	0.5218269	2.429965	4.475489
8	7	Basin	Patoka	Macro	Variance	12	3.696555	1.1792038	1.385358	6.007752
9	8	Basin	Patoka	Macro	Std. Deviation	12	1.922643	0.3066622	1.321596	2.52369
10	9	Basin	Patoka	QHEI	Total	26	19480.8679	1086.8917	17350.5993	21611.1364
11	10	Basin	Patoka	QHEI	Mean	26	47.939271	1.1806176	45.625303	50.253239
12	11	Basin	Patoka	QHEI	Variance	26	70.733128	11.5330523	48.128761	93.337495
13	12	Basin	Patoka	QHEI	Std. Deviation	26	8.410299	0.6856506	7.066449	9.754149
14										
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Ready

NUM

Start | Exploring - Patoka | Microsoft PowerPoint - [In... | Microsoft Word - Summar... | Microsoft Excel - sc... | 4:29 PM

Patoka: Fish IBI Score CDF Estimate

Sampled						
Landowner Denial	4	5.69	1.44	9.94	60.87	15.40	106.34
Physical Barrier	1	1.08	0.00	2.91	11.52	0.00	31.09
Sampled Chemistry Not Biology	23	37.08	26.15	48.01	396.49	279.60	513.38
Non Target	10	18.15	8.96	27.35	194.13	95.80	292.47
Total	64	100.00	NA	NA	1069.38	NA	NA
Target Population	54	81.85	72.65	91.04	875.25	776.91	973.59
Non Target	10	18.15	8.96	27.35	194.13	95.80	292.47
Total	64	100.00	NA	NA	1069.38	NA	NA

Estimates based on Target Sampled sites applied to the Sampled Population
(Summary of information in R output file: ibigheisum.csv)

Indicator	Status	No. Sites	Percent Resource	LCB 95%	UCB 95%	Extent (km)	LCB 95%	UCB 95%
Biology& Water Chemistry	Impaired	18	**70.85**	56.15	85.55	620.12	491.43	748.80
	Not Impaired	8	**29.15**	14.45	43.85	255.13	126.45	383.82
	Total	26	100.00	NA	NA	875.25	NA	NA

Using Probabilistic Results to Predict the Percentage of Stream Miles Not Attaining Aquatic Life Use

6. Assessment for River Basin

Project Name	Target Population	*%Attainment*	*%Non-Attainment*	Confidence Level	*Confidence Interval*
West Fork	05120201	69%	31%	95%	15%
White River	05120202		1st order=4		
n=36	05120203		2nd order=5		
1st=13			3rd order=2		
2nd=14			4th+ order=0		
3rd=4			n= 11/36 Impaired		
4th+=5					
Patoka River	05120209	29%	71%	95%	15%
n=26			1st order=4		
1st=5			2nd order=7		
2nd=11			3rd order=0		
3rd=3			4th+ order=7		
4th+=7			n=18/26 Impaired		
Target population = 8 digit HUC					
%Attainment = Combined Assessment of Biology (IBI>35, mIBI>2.2,HD>1.4) and No Chemical Parameter Violations					
%Non-Attainment = Combined Assessment of Biology (IBI<35, mIBI<2.2,HD<1.4) and Chemical Parameter Violations					
The Confidence Interval is the %Non-Attainment +/- the value for 95% Confidence Level.					
* These are values produced by IDEM staff using "R" (http://cran.us.r-project.org/) and commands provided by					
USEPA National Health and Environmental Effects Research Laboratory, Corvallis, Oregon.					

Second Year Source Identification Sampling

Original Intent of Surface Water Quality Monitoring Strategy

1. Find Impairments

2. Return to impairments the next year to find source

3. Assessments for Integrated Water Monitoring & Assessment Report

Reality: Limited success implementing second year studies

2004: Second Year Source Identification Fully Implemented

– USGS collecting water chemistry and nutrient data
at probabilistic sampling sites

– Shift field season schedule for biological sampling to
June rather than July

– Prioritize watershed source identification studies

– Shifting and hiring of staff to form new crews
targeting impaired watersheds

Second Year Source Identification Sampling

- **Extensive Chemical Sampling**
(impaired sites due to pollutants or point sources)

- **Extensive Biological & Chemical Sampling**
(impaired sites due to biological impairment)

– Background research of potential sources

– Approximately 30-40 sites per watershed (4-6 watersheds/summer) to determine cause and source of biological impairment

- **Products**

– Know extent of impairment and source for stream segment assessments

– Proper listing of the waterbody in Categories 1-5 on the 303(d) List of Impaired Waterbodies

– Data for TMDL development if needed and watershed restoration plans

– Referrals to Inspectors, County Sanitation Districts and Department of Health

– Potential Water Quality Criteria Revisions

Advantages & Disadvantages of Probabilistic Sampling

- **Advantages:**

  – **100% waters of the state assessed**

  – **monitoring long term watershed trends**

  – **discovering non-point source pollution**

  – **finding impairments at distant remote sites**

  – **can focus resources to watershed specific impairments**

  – **Bonus: biological expansion of species distribution, Threatened & Endangered Species, educate public and landowners in watershed**

- **Disadvantages:**

  – **Time, Access, Safety**

  – **Cause and source of impairment**

  – **Basins sampled only once every 5 years**

  – **Where are the other impairments?**

Photo Credit: Rob Criswell

Bluebreast Darter, *Etheostoma camurum*

Conclusions

- **Probability Monitoring**
  - Completed one cycle, after 2005 2nd cycle will be completed!
  - Assess 100% of the waters of the state for the Integrated Water Monitoring and Assessment Report

- **Follow up impairments with second year source id**
  - intensive surveys both biological and chemical in impaired watersheds
  - evaluate tiered aquatic life uses for modified streams

- **Need:**
  - Numeric biocriteria
  - Refined-designated uses
  - Model to predict where impairments might occur
  - Determine cause and source for Impaired Biotic Communities already listed

Acknowledgements

- Dennis Clark, Assessment Branch Chief
- C. Lee Bridges, Biological Studies Section Chief
- Arthur Garceau, Surveys Section Chief
- Tony Olsen, USEPA NHEERL Corvallis, Oregon
- Assessment Branch Staff